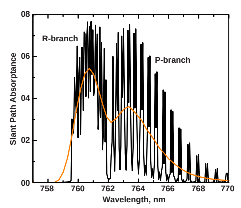
Satellite Remote Sensing of Temperature and Pressure by the Stratospheric Aerosol and Gas Experiment (SAGE III)

SAGE III O2 A-Band Measurements

SAGE III Background

- Fifth generation of solar occultation instruments designed to measure vertical profiles of aerosols and gaseous species (see poster 4.52B for overview of SAGE III)
- Utilizes multi-spectral measurements of O_2 A-band to infer profiles of temperature and pressure
- T/p profiles will extend from surface (or cloud top) up to 85 km with ~1 km vertical resolution



This figure depicts the oxygen A-band slant path absorption spectrum for a tangent altitude of 20 km. The red line illustrates the SAGE III spectral resolution.

O_2 Measurement Specifications

- 14 channels equally spaced at ~ 1 nm intervals from approximately 759 to 771 nm
- Spectral resolution of each channel is ~ 1.4 nm
- High signal-to-noise measurements (~3000)
- Radiative transfer in A-band dominated by O_2 absorption with small contributions from aerosol extinction, O_3 absorption, and molecular scattering

Temperature and Pressure Retrieval Algorithm

Based on global fit (Carlotti) approach: T,p profiles determined in single step by simultaneously fitting measured absorption spectra from all channels and slant paths

Iterative procedure attempts to minimize residuals between measured and modeled absorption spectra by adjusting a "working" T,p profile until convergence is reached

Updating equation:

$$\Delta\chi^2_{min} = \Delta\chi^2_{curr} + \frac{\partial \Delta\chi^2}{\partial a_l}\, \delta a_l$$

where a_l are the temperatures and pressures at each tangent altitude and the χ^2 merit function is defined as:

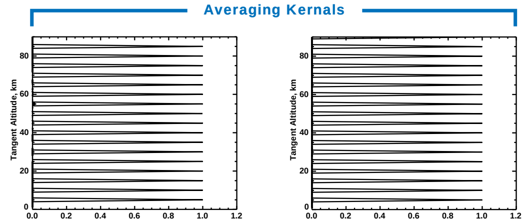
$$\chi^2(\vec{T}, \vec{p}) = \sum_{j=1}^{M} \sum_{i=1}^{N} \left[\frac{A_j^m(\lambda_i) - A_j^c(\lambda_i; \vec{T}, \vec{p})}{\sigma_{ij}} \right]^2$$

where $A_j^m(\lambda_i)$ are the measured O_2 absorption values for slant path j and channel i and $A_j^c(\lambda_i;T,p)$ are the computed absorption values for the same slant path and channel.

Retrieval Characterization

We have begun a detailed characterization and error analysis of the T,p retrievals based on the formal analysis of Rodgers (1990). In this formulation, the "averaging kernels" are determined by evaluating the response of the retrieval to a d-function perturbation. The width of the "averaging kernels" is a qualitative measure of the resolution of the retrievals. The "averaging kernels" for temperature and pressure are shown in the figures below.

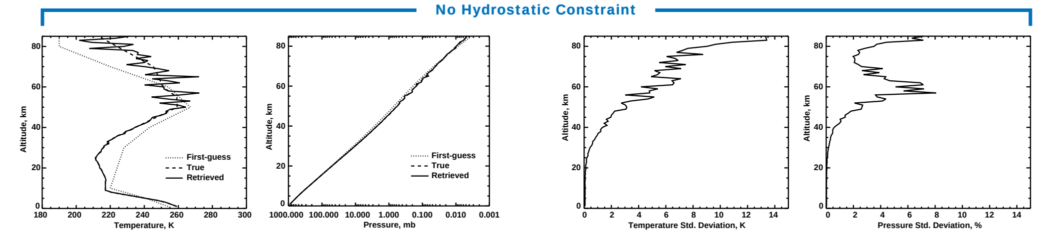
Averaging Kernals



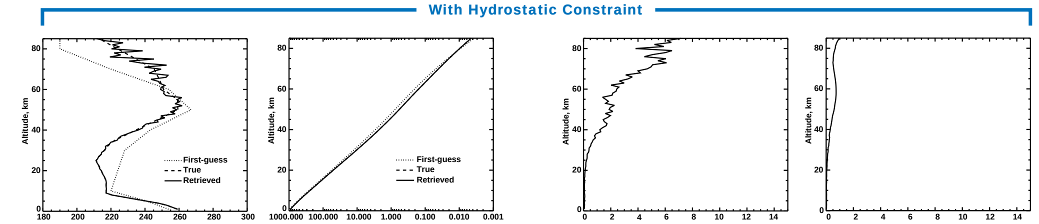
Simulated Retrievals

The following are examples of retrievals performed using simulated SAGE III O_2 slant path absorption measurements that included a realistic component of random noise. The first two examples illustrate the improvement in the solution when a "passive" hydrostatic constraint is employed. The third example shows the capability of SAGE III to resolve gravity waves. The top two panels in each example show the retrieved T,p profiles compared with the first-guess and true T,p profiles. The bottom two panels show the expected 1-s uncertainties in the retrieved T,p profiles.

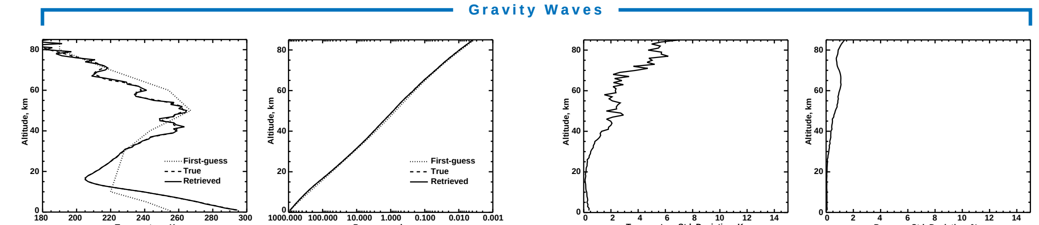
No Hydrostatic Constraint



With Hydrostatic Constraint



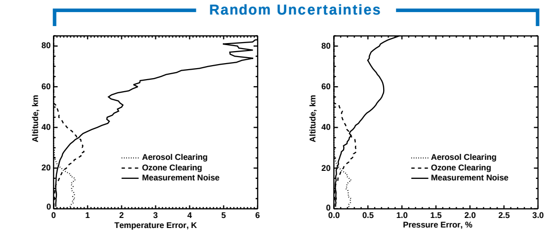
Gravity Waves



Measurement Uncertainties

- Dominant component due to random measurement noise (SNR ~ 3000)
- Additional components associated with clearing interfering species (aerosol and O_3)
  - Aerosol: ~ 1% of aerosol slant path optical depth
  - O_3: ~0.5% of O_3 slant path optical depth
- Relative uncertainties due to each component are shown in figures below

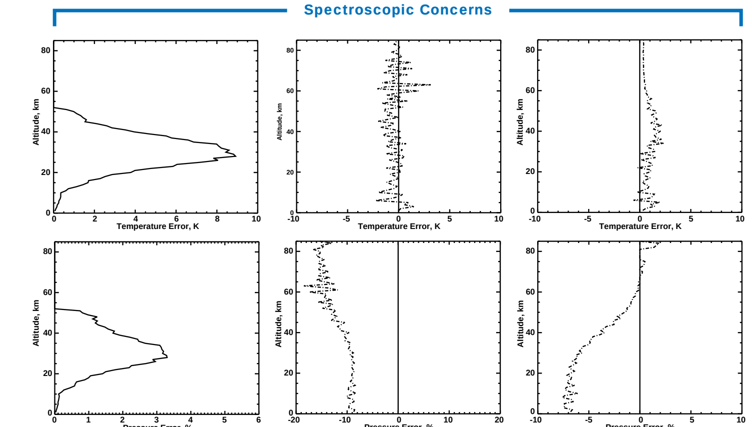
Random Uncertainties



Sources of Random Uncertainty

- Currently using HITRAN96 database
  - Wide discrepancy in available line parameter data
  - Range of line strengths ~15% and line widths ~30%
- O_3 Wulf band cross-sections
  - Estimated uncertainties of ~5%
  - Impacts ability to accurately clear O_3
  - Temperature dependence not well documented

Spectroscopic Concerns



A 5% bias in the O3 Wulf band cross sections | A 15% bias in the oxygen A-band line strengths | A 15% bias in the oxygen A-band line widths

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